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ABSTRACT

Progress on the development of a mathematical model and associated computer programs for use by the Illinois State Library in evaluation and planning of the interlibrary loan (ILL) network is summarized. Pertinent published literature on ILL networks is reviewed in terms of network structure, operations, satisfaction of requests, and costs. A flow chart model of the Illinois ILL network is outlined, and then alternate approaches are considered for the mathematical modeling of an ILL network. Network flow theory and simulation are discarded in favor of a hierarchical queueing network which will be analyzed using approximations that will be validated with simulation. An initial version of this model, named ILLINET, has been programed into an on-line interactive package where the user can input alternative network operating policies and test the effect on average delay in satisfying a request, probability of satisfying a request, total network operating costs, and unit costs. Six possible hardware applications of computer and communications technology are discussed, ranging from simple telephone and WATS line to the possible use of a computer to control the whole network.
(Author/SL)

A MATHEMATICAL MODEL

OF THE

ILLINOIS INTERLIBRARY LOAN NETWORK

Project Report No. 1

Submitted to

Illinois State Library

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FOREWARD

This is the first in a series of reports resulting from a research grant to the Coordinated Science Laboratory, through the Library Research Center, of the University of Illinois at Urbana-Champaign. The sponsor of the grant is the Illinois State Library under the Illinois Program for Title 1 of the Federal Library Services and Construction Act.

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I. INTRODUCTION AND SUMMARY

This report summarizes progress on the development of a mathematical model of the Illinois interlibrary loan network. This project is funded by the Illinois State Library and is being carried out at the Coordinated Science Laboratory of the University of Illinois at Urbana-Champaign.

The main objective of this project is to produce a mathematical model and associated computer programs for use by the State Library in evaluation and planning of the interlibrary loan (ILL) network. While this goal is rather specific, we are endeavoring to develop a general understanding of ILL networks and a general model of their operation. With this point in mind, we have written this report with a broad perspective in the hopes that our results and conclusions to date will be of use to the research community.

Section II summarizes the pertinent published literature on ILL networks. This literature is reviewed in subsections on network structure, operations, satisfaction of requests, and costs. A general conclusion reached is that, while much is happening in the area of ILL networks, little solid analytical work is available. The authors hope to make a contribution in this area.

Section III discusses a flow chart model of the operations of the Illinois ILL network. In this section, we try to develop a flow chart that adequately represents the network without being so complicated that it is analytically intractable.

Section IV considers approaches to developing a mathematical model of an ILL network. A review of the pertinent literature is presented. Network flow theory and simulation are discarded in favor of a hierarchical queueing network which will be analyzed using approximations that will be validated with simulation. An initial version of this model is discussed. This model has been programmed into an on-line interactive package where the user can input alternative network operating policies and can see the effect upon average delay in satisfying a request, probability of satisfying a request, average processing load on each member of the network, total network operating costs, and unit costs. This computer package has been entitled ILLINET to correspond with the State Library's acronym for Illinois Library and Information Network. In this section, we also discuss the changes that will be incorporated into the model in the near future.

Section V discusses six possible hardware applications of computer and communications technology. They range from single telephone and WATS line to the possible use of a computer to control the whole network. Some of these alternatives will be further investigated to consider how they would affect the functions discussed in Section III. These effects will then be input to ILLINET and we will then be able to predict the impact of these technological alternatives on overall network operation.

The main purpose of this report is to discuss ILL networks and how their operations can be analyzed. We have surveyed the state-of-the-art and feel that we have determined the most realistic approach to modeling and predicting ILL network behavior. Future reports will consider the mathematics involved, the ILLINET model and computer programs, and the application of the model to evaluation and planning of the Illinois ILL network

II. SELECTED REVIEW OF THE LITERATURE ON ILL NETWORKS.

The documents discussed in this section of the report are limited to publications from 1971-1974 which describe ILL network operational characteristics or evaluate and quantify ILL network performance. Based on the published reports of library networks we will discuss the following aspects of ILL networks:

a. Structure,

b. Operations,

c. Success rate,

d. Costs.

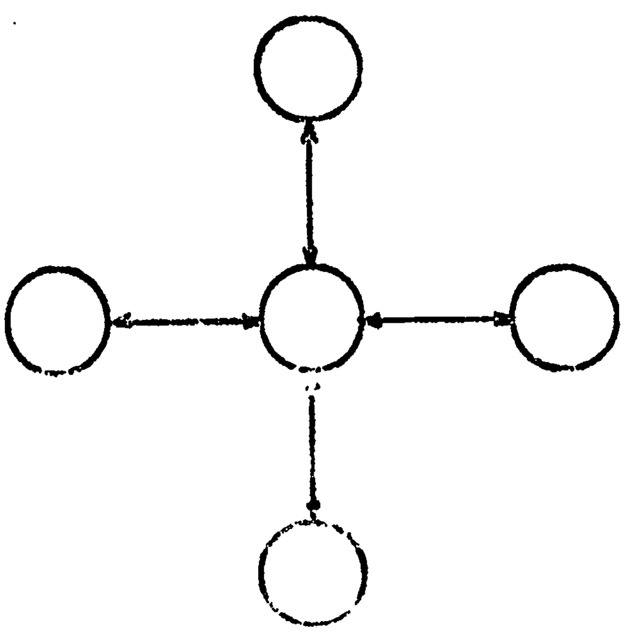
Network structure refers to the elements, configuration, and levels of a network. After presenting some examples of network structures we will focus on the nature and mode of operations of ILL networks, namely message transfer and document delivery. Defining network structure and operations will provide the necessary framework, within which we will finally discuss what has been reported relative to processing time, satisfied requests, and costs. Two lists at the end of this section give a brief description of four regional centers which provide ILL service and the State ILL networks found in the literature covered in this report.

A. Structure.

The structure of library networks can be described in terms applied to computer networks. However, an important difference between library and computer networks is in the operations they perform which we will discuss in the following section. Network structure can be discussed in terms of elements, configuration, and levels.

The elements of a library network consist of nodes, or processing centers and links, or possible paths of communication. The pattern which results when nodes and links are connected is the network configuration. Network configurations do not necessarily reflect network procedures which define protocols or the order by which network activity progresses. Several researchers have analyzed network structure in terms of network flow theory to describe the activities of the network and the availability and utility of connecting links [20,43,50,51]. The problems and characteristics of communication networks are not the same for library networks. Using the terms computer or communication network and library network interchangeably is confusing and often not correct [3]. Specific discussion of network modeling and analysis is presented in Section IV.

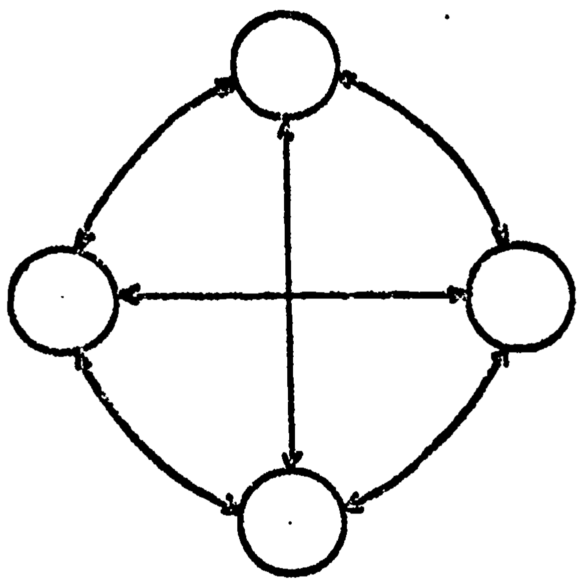
A totally centralized network is described by the star configuration in Figure 1. Activity or services provided by the network are controlled by the central node [13]. As an example of a centralized network, consider the New York State Library which receives ILL requests and refers the unfilled requests among 12 libraries (3 public or area libraries and 9 research or subject libraries) [22].



STAR CONFIGURATION

FIGURE 1.

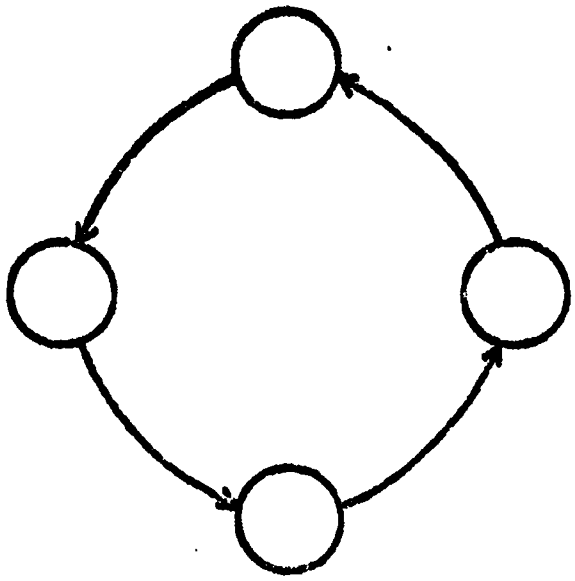
Communication routes do not exist between the outer nodes of the purely centralized network. All communication is controlled via the central node. By contrast, the completely decentralized network can be described by the distributed configuration in Figure 2 [47]. As the figure illustrates each node has the alternative of communicating with every other node in the network. There is no rank or order imposed on the communication links.



DISTRIBUTED CONFIGURATION

FIGURE 2.

A third configuration commonly used to describe network structure is the ring in Figure 3 [47]. Like the distributed network there is no central processing node. The distinguishing characteristic of the ring structure relates to the communication or processing order. Once a request enters the network at a given node i and futher processing of that request is necessary, the request can only be sent to node i + 1.



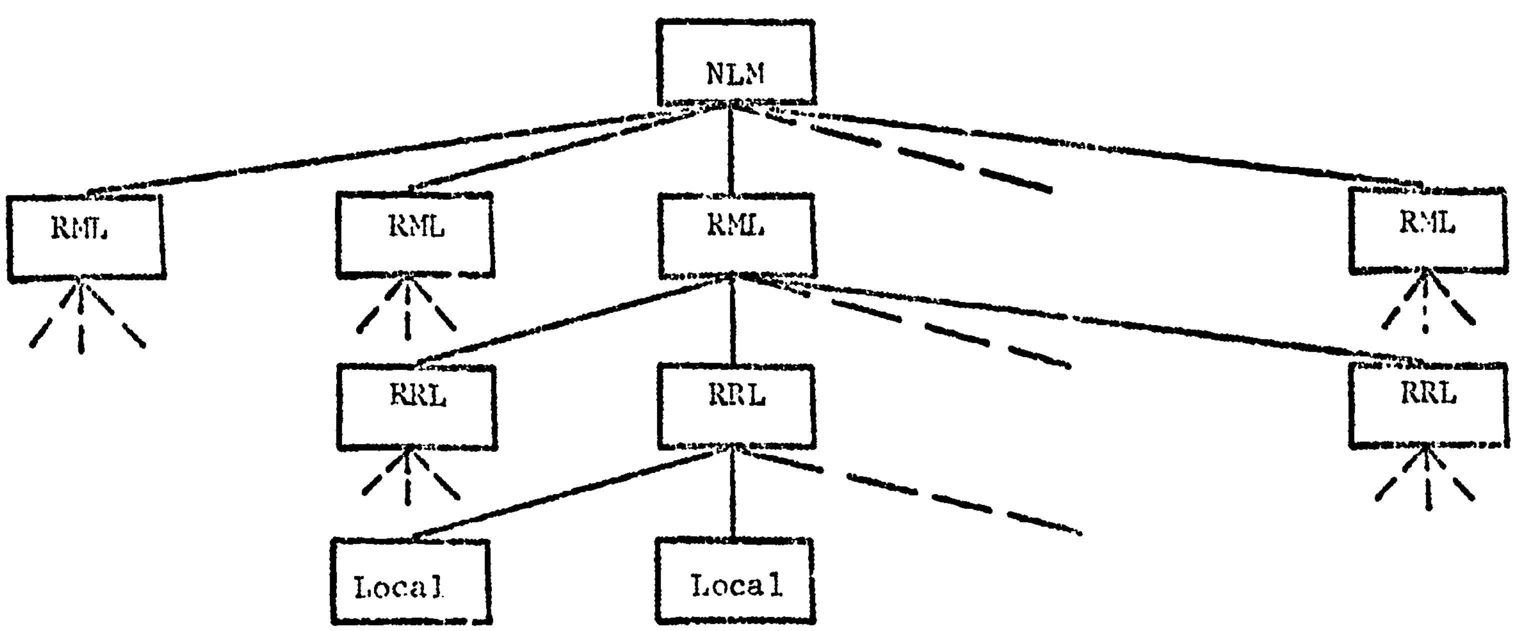
RING CONFIGURATION

FIGURE 3.

Communication between the System and Center levels of the Illinois Interlibrary Loan Network can be described as a structure which is a compromise between the distributed and ring configurations. While the Research and Reference Centers can communicate with every other member of the network, the Systems can, but usually do not, communicate with all the other network members. (See Section III for further discussion).

This leads us to another aspect of library network structures. We can visualize the activity of most library networks along two directions, lateral and vertical. A request that is routed laterally is sent between two nodes with roughly equal responsibility (e.g., similar size of geographical area or similar number of subject specialities). Vertical routing refers to movement in a hierarchy. As we move up in the hierarchy, there are usually fewer nodes each of which has greater responsibility and access to more comprehensive collections.

As an example of a hierarchical network, consider the Regional Medical Library Program. The primary activity of the Regional Medical Libraries is document delivery [12]. The hierarchical structure of this network is described by four levels: (1) local libraries in hospitals, junior colleges with health science programs, government agencies; (2) resource libraries, usually in medical schools; (3) RML, 11 regional libraries covering defined geographic regions; (4) NLM, in addition to serving as an RML for the Mid-Atlantic Region, it also serves as the final resource for those requests unsatisfied after the 3rd level of processing [12,67]. Figure 4 illustrates the hierarchical structure of the NLM network.

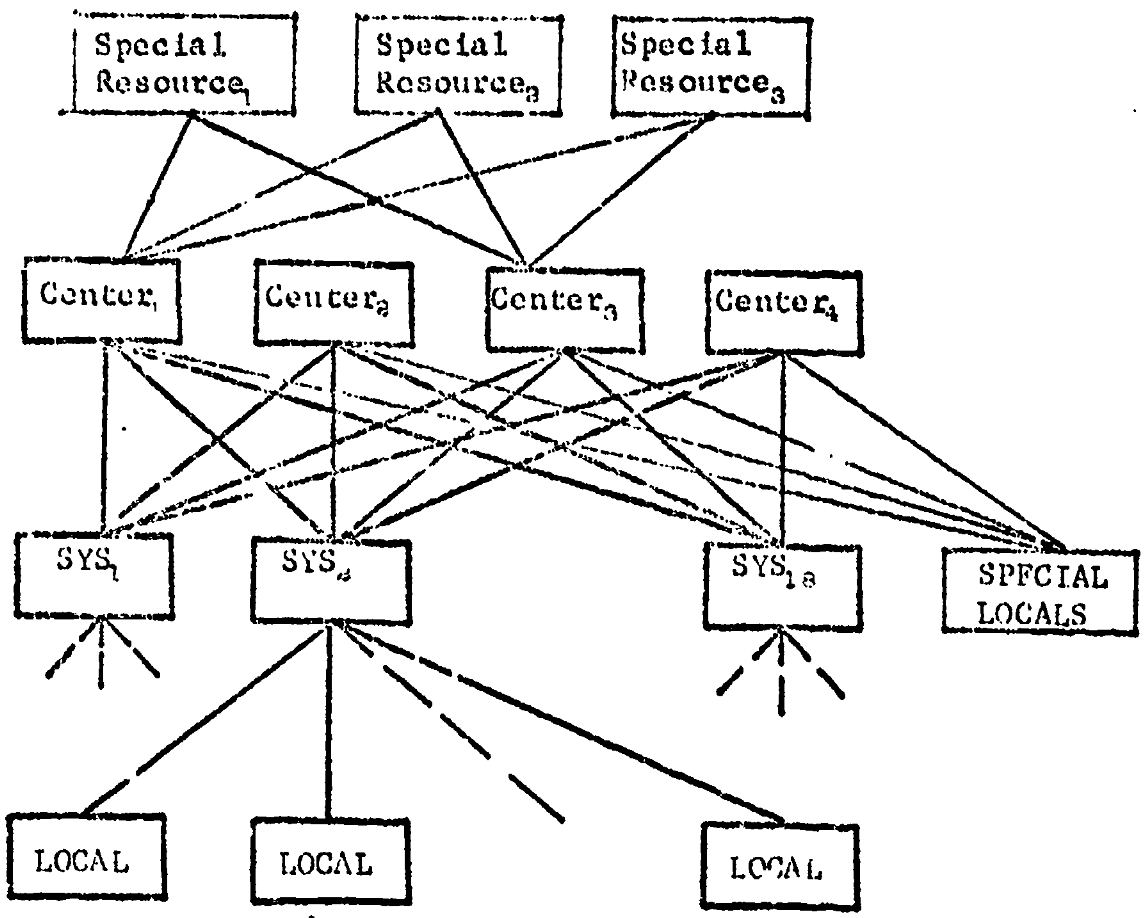


HIERARCHICAL STRUCTURE

NLM NETWORK

FIGURE 4.

Similarly the Illinois ILL network can be described as a hierarchical structure with four levels: (1) local libraries, public, academic, and special with collections under 200,000 volumes; (2) 18 Systems libraries, (primarily responsible for a geographic region of local libraries and with some Systems libraries maintaining special subject strengths) and potentially, 16 large academic libraries with collections in excess of 20,000 volumes; (3) 4 Research and Reference Centers, 1 special library, 2 academic libraries, and 1 public library; (4) Special Resource Libraries. Processing of requests generally moves in an upward (vertical) direction similar to the NLM network. The requests initiated by the local level and processed as nofills by the Systems libraries, are then routed to the Center level and possibly to the Special Resource Library level. Figure 5 illustrates the hierarchical structure of the Illinois ILL network.



HIERARCHICAL STRUCTURE

ILLINOIS ILL NETWORK

FIGURE 5.

This description of the structure of NYSILL, NLM and Illinois ILL networks has purposely simplified the structures of these networks in order to exemplify the network structures frequently mentioned in the literature [13,43,47]. The actual operations of these networks generate network structures too complex to describe for practical purposes in this report.

Duggan offers a model for predicting optimal network design with respect to some measures of network performance which she has developed [19]. The collections of libraries in a hierarchical network tend to have more comprehensive collections in the upper level of the hierarchy. This is usually reflected in a progressively higher fill rate as one travels from the lowest level to the top of the network.

Davis points out that the heirarchical network enables one to cluster activities based on some criterion, such as organizational priorities, or processing activity. A second feature of the hierarchical network offers alternative routing paths, unlike the completely centralized or decentralized structures [13].

The influence of structure on network performance played a important role in the design of the biomedical ILL network. In 1963, it was predicted that medical resources libraries would free a demand of 1.5 million requests per year by 1973. Because the existing resources for processing ILL requests could not possibly handle this projected increase in demand, a reorganization of the Biomedical Information System resulted in the hierarchical network previously described [66].

Swank comments on the lack of systematic study of information network structures. He notes that an important area of research barely explored is determining the optimum size of networks for different levels of activity [79]. Miller brings our attention to a similarly related problem by asking how does the network manager decide that a given level of the network no longer exists operationally and that formal reorganizing is necessary [46]. From the perspective of the library manager, one might ask what criteria and measurements indicate that a library can no longer operate economically as a self-sufficient library. Scanning the literature between 1971 and 1974 reveals no analytical studies which answer these frequently asked questions.

B. Operations.

Library network operations can be categorized by two services: message transfer and document or information delivery. Analysis of a message transfer service emphasizes the process by which a message is transferred, i.e., some alternatives might be telephone, TWX, computer, or telefacsimile. By contrast, the analysis of a document delivery service places emphasis on investigating the processing of a request after the message has been transferred.

Need for an effective national document delivery system is recognized by the Association for Research Libraries which is reportedly investigating the feasibility of a national computerized document transfer network [4]. In a recent publication, Hayes addresses the technical, operational, managerial and economic feasibility of a national message transfer network for ILL activities [30].

Since document delivery operations exist in most ILL networks we will discuss the experiences of various library systems using the following delivery mechanisms:

1. Shuttle,
2. Telecommunication,
3. Mail,
4. Computer-controlled mechanized retriever.

Evaulating a shuttle delivery service usually considers the following factors:

1. Distance or geographic area serviced,
2. Frequency of arrivals and departures per unit time,
3. Number of requests per unit time.

Library networks reporting their experience with a dedicated shuttle service include Five Associated University Libraries [65], NYSILL [38], Ontario Council of University Libraries [18], Utah College Library Council [28] and Worcester Area Cooperating Libraries [14]. NYSILL's experiment with the shuttle service resulted in delivery which was faster than 1st or 4th class mail while the cost per shuttled transaction was inversely related to demand [38]. The Utah College Library Council, consisting of four libraries each with TWX facilities and microfilmed catalogs, operated a daily shuttle which provided 24 hour turnaround time for requests with a cost of $.31/document delivered [28].

Endorsement of telefacsimile transmission has not been as clearly voiced as shuttle versus mail delivery. Many studies report that a low level of demand renders telefacsimile too costly compared to mail or shuttle services [9,29,57,75,82]. In spite of predicted increase in the use of telefacsimile by businesses [25] and improvements in quality [11], rigorous analytical studies investigating the tradeoffs between demand, unit costs, and benefits are needed before making recommendations for or against telefacsimile in ILL networks [3,24].

Some library systems experiencing "success" with telefacsimile are Penn State University [37] and Nebraska [59]. Penn State claims that their service provides a telefacsimile transmission for $1.79 per page if use of the system is at least 50% of the maximum usage and the state subsidizes unlimited wide area facilities. (Maximum usage is defined as transmitting 1,733 pages per month or 10 pages per hour.)

TWX facilities are frequently used in communicating the status of ILL requests. A Westat survey found that nearly 65% of the ILL requests from public libraries were sent via TWX while only 20% from academic libraries were sent in that manner [62]. These figures suggest a relatively faster communication of ILL requests by public libraries than academic libraries. Indiana reports favorable experience with TWX facilities [83,84].

The following variables are usually considered in evaluating TWX communicated ILL requests:

1. Communication line cost,
2. Terminal cost and type,
3. Speed of delivery compared with mail or shuttle.

Braude and Holt present a model to guide the decision maker in comparing mail versus TWX transmission of ILL requests [7]. A key factor in the decision making process is the accurate identification of benefits to the user and overall network performance. For example, the library manager must be able to quantify alternative points where users are willing to pay an increase of x dollars for a service which promises to decrease the present service time by y percent. In addition to the individual user's benefits the manager must also weigh the impact of these alternatives on overall network performance [21]. Shanok and Quinton developed a model which offers guidelines for evaluating a teletype communications network and considers the tradeoff between half and full duplex teletypes and delays in computer processing [76].

Two computer-controlled retrieval and return systems were compared for the Five Associated University Libraries Network [16]. They found that with either the Randtriever or Yale system, a request can be initiated and the document retrieved (as opposed to delivered) in 25 seconds. They compared this to 10 days with conventional retrieval in a decentralized environment. Of course, the 10 days includes many operations not included in the 25 seconds and thus a comparison of these numerics is not really justified. The result of the experiment found that demand was too low to justify the cost of the mechanized systems and central storage.

Speed of delivery, cost per request and impact on overall network performance are the variables frequently mentioned when evaluating delivery mechanisms of library networks. Brigitte Kenney's question points the direction for needed research: "How much is the user's time worth as compared to that spent by the network in speeding his request on the way?" [40]. Pings mentions the need to evaluate user satisfaction and administrative effectiveness with respect to time spent processing the request and delivering the document [68]. Unfortunately the report offers no model or analysis for the decision maker once the data has been collected.

C. Success Rate.

The rate of success for satisfying ILL requests is another important measure of a library network's performance. The following factors which Thomson mentions [81] are usually related to the ILL success rate:

1. Size of the library,
2. Distance to lending library,
3. Characteristics or material requested (language, date, etc.,),
4. Verification of request,
5. Union lists.

The difficulty with comparing network success rates stems largely from not knowing explicity what processes a specific network performs and not knowing their definition of success.

Warner offers an elementary measure of network and library effectiveness which simply is the ratio of satisfied to total number of requests [86]. Looking at the same problem, measuring success rate, Duggan [20] proposes to look at the borrowing-lending transactions of the network libraries. The dependency of a library is measured by

$$\frac{\text{Number of Borrowed Requests}}{\text{Total Number of Borrow-Lend Transactions of the Library.}}$$

The measure of library participation is the ratio

$$\frac{\text{Total Number Borrow-Lend Transactions of the Library}}{\text{Total Number Borrow-Lend Transactions of the Network}}$$

Evaluation of the NYSILL pilot project brought attention to the problem of identifying which requests could have been filled if the criterion for appropriate library collections were more accurate and alternative routings were possible [55]. In a later Nelson Report the fill rates for public libraries was found to be inversely related to size of the collection of the library initiating the request. Academic libraries rely less on NYSILL than public libraries and the size of their collections did not appear to significantly effect their probability of being satisfied [56]. Based on a sample (8 libraries) of the largest lending academic libraries Thomson found that the lending librarian's verification of requests not found in their library catalogs was the most important factor related to increasing the success rate [81].

Considering the reasons for unfilled requests in the NYSILL network it was found that the quality of citations for unfilled requests does not significantly differ from that of filled requests. About 85% of these unfilled requests were owned by at least one of the network libraries.

It was recommended that corrections in searching and routing errors would have resulted in locating 56% of the unfilled requests [22].

The TALON (Texas, Arkansas, Louisiana, Oklahoma, and New Mexico) Regional Medical Library Network employs an on-line management information software package which generates monthly reports and cumulates yearly statistics. TALON headquarters acts as a switching center by accepting loan requests and routing them to appropriate libraries. Statistics generated include total number of requests, number filled, and response time for filled and unfilled requests [52].

Union catalogs are an important factor influencing the fill rate of library networks. A study at Delhi Library of the Indian Institute of Technology confirmed that the lack of a union catalog center was the most significant factor responsible for a low fill rate for ILL requests [39]. In the NLM network, use of on-line bibliographic retrieval offered by Medline will soon supplement interlibrary loan activities. The SERLINE data base which provides library location of serials and journals, will be used to automatically switch ILL requests to the lending library containing the desired serial [12].

D. Costs.

Costs for processing ILL requests are generally influenced by the following variables:

1. Size of the network--number of demands per year, size of staff, and volumes in total collection,
2. Centralized or decentralized collection,
3. Standards of service,
4. Processing time per request,
5. Technological support, and
6. Salary scales [45].

The lack of cost analyses for information network performance is noted by Davis [13] as well as the Computer Science and Engineering Board of the National Academy of Science [53] which recognizes the need for scientific modeling of information networks to consider costs for different levels of service. In a paper by Brookes the problem of distribution of collection development in a hierarchical library network is analyzed with respect to user needs and the library manager's funding [8].

The Washington State Library sponsored a study investigating alternative ILL network structures which would provide at least the same level of service existing at the time of the study [73]. The present system had no formal centralized ILL activities. Loans were made from the local-to-local library level and from a local library to the State Library. Two alternatives proposed were a regional system clustering local libraries by geographic proximity and a State system where the State Library would serve as a centralized service point.

While the results of the study show that the State system would cost less than either the current or proposed regional system, the benefits associated with the 3 alternative plans must also be considered. Increased collection availability would result from both network configurations with the State system providing the greatest number of available titles. The report also mentions that future development of library resources might be facilitated by the regional and State network structures. Operating in an environment which provides a larger volume of information in probably less time, would generate a higher volume of activity. The libraries in the State would thus be in a position to benefit from cooperative cataloging and acquisitions, supported by advanced library automation. The study points out that while overall State costs may decrease by implementing the centralized State Library network, the distribution of local library savings may vary widely.

Fees charged to requestors of interlibrary loans poses a perplexing dilemma to library administrators who often predict a devastating loss of clientele. The Arizona Medical Library Network provided a free ILL service supported by a federal subsidy [66]. The program was to become self-supporting and thus federal funds were eventually removed. Consequently, requestors were suddenly charged for a service that was once "free". The result was a drop in demand by 50%. Within a year, however, the Arizona network regained its past level of activity and rising demand rate by introducing a cost recovery method.

At another medical network, KOMRML (Kentucky, Ohio, Michigan Regional Medical Library), the high demand for ILL requests and decreased NLM funding forced the network to operate on a quota system, limiting the number of free transactions per institution [48]. Evidence suggests that paying for library services does not appear as unsuccessful as some might believe.

A 1972 Westat report estimates costs of academic interlibrary loan transactions based on 12 libraries, a sample of the largest academic lending libraries in the nation [62]. One of the interesting results of this study is that transaction costs appear more directly related to geographic location than collection size. In a more recent study Palmour recommends a temporary fee schedule for ILL requests which should eventually be replaced by federal and state subsidies [64]. Other examples of cost studies for particular ILL networks can be found in the following articles [58,60,63,77].

E. Summary

The purpose of this section has been to report the current state-of-the art of interlibrary loan networks. Emphasis was placed on network operations and measures of network performance. The following variables affecting network performance were discussed in the context of the literature selected for this report:

1. Structure,
2. Operations,
3. Success rate,
4. Costs.

Mathematical modeling and analysis of networks is covered extensively in Section IV.

The following two lists summarize four regional centers which provide ILL service, and the State ILL networks mentioned in the literature selected for this report. A description of these ILL activities can be found in Kruzas' Encyclopedia [23]. Fuller discussion of these networks and ILL activities can be found in the reports indicated by the reference numbers in the lists.

CENTER (Ref.)	STATE	STATES COVERED
Bibliographic Center for Research (31)	Colorado	Arizona, Colorado, Iowa, Kansas, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Utah, Wyoming
Center for Research Libraries (88)	Illinois	About 80 member institutions in the U.S.
National Library of Medicine (12,67)	Maryland	11 Regional Medical Libraries
Ohio College Library Center (34)	Ohio	About 60 member libraries within Ohio and services also extend to NELINET; New Mexico, New York, Pennsylvania, SOLINET

FOUR REGIONAL CENTERS PROVIDING ILL SERVICE.

NETWORK (Ref.)	STATE	SIZE
Illinois Interlibrary Loan Network (63)	Illinois	Illinois State Library as 1 of 4 Resource and Reference Centers 18 Regional Systems
Interlibrary Communication Network (83,84)	Indiana	Indiana State Library 4 State Academic Libraries 14 Public Libraries
MINITEX (78) (Minnesota Interlibrary Teletype Exchange)	Minnesota	11 Regional Libraries
NYSILL (22,38,55-57,60,82) (New York State Inter-Library Loan)	New York	New York State Library 3 Area or Public Libraries 9 Subject or Research Libraries
OTIS (23) (Oklahoma Teletype Interlibrary System)	Oklahoma	Oklahoma State Library 14 Referral Libraries
Pittsburgh Regional Library Center, Inc. (36)	Pennsylvania	Carnegie Library of Pittsburgh 26 Academic Institutions
Regional Reference and Information Networks (23)	Ohio	Ohio State Library 5 Regional Networks
SCAN (36,73) (State Controlled Area Network)	Washington	Washington State Library 7 Regional Libraries

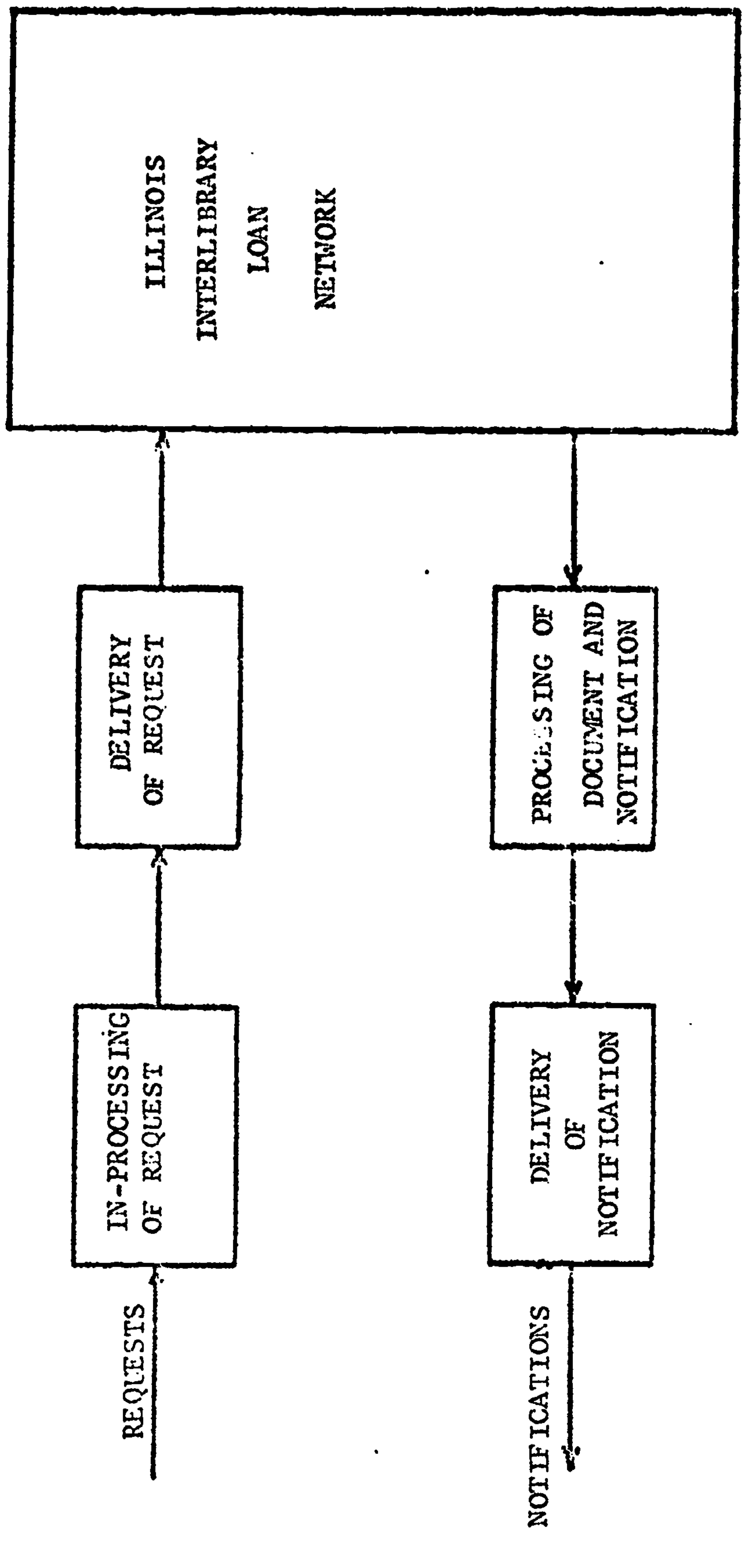
STATE ILL NETWORKS REPORTED IN THE LITERATURE.

III. THE ILLINOIS INTERLIBRARY LOAN NETWORK

To develop a mathematical model of the Illinois ILL network, we need a concise representation of how the network operates. Such a representation must be simple enough to allow analysis yet of sufficient detail to capture the essence of the network's operations. Any representation is necessarily approximate and thus does not exactly describe how every request is processed by the network. A good representation is one that adequately describes how most requests are processed. Figures 6 through 8 and the discussion that follows are our representation of the Illinois network.

The network is hierarchical and has four levels: local libraries, Systems, Research and Reference Centers and Special Resource Libraries. A functional block diagram of the local level is shown in Figure 6. In general, a block or box represents a process that consumes time. The amount of time consumed depends on the process and may, within some range, be a random variable. The lines between blocks represent the flow of requests, documents, and notificatioı

The time between arrivals of requests (interarrival time) is not a constant and may be viewed, again within limits, as a random variable. Similarly, all flows in the network may be thought of as having somewhat random interarrival times. Thus, in Figure 6 we have a probabilistic flow of requests into a local library. Requests suitable for utilization of the ILL network are processed in the sense of filling out the proper forms. The request is then delivered to the System in which the local library is located. Some time later, the request or document returns, is processed, and the patron is notified. Once the patron is notified, the ILL process is complete. Thus, we are not concerned with the time it takes for the patron to respond to the



LOCAL LEVEL OF NETWORK

FIGURE 6

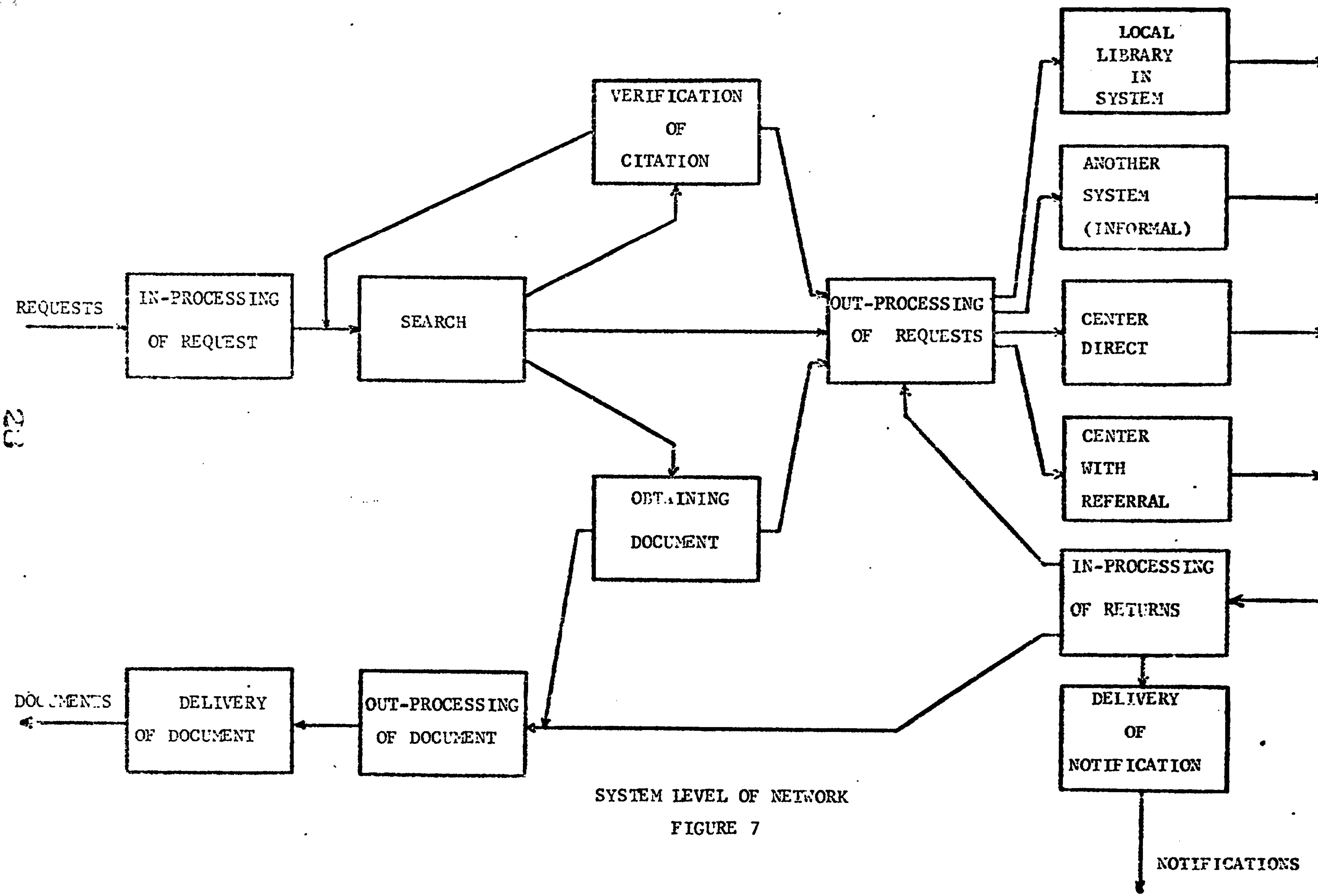
notification. Neither are we considering the process of returning the document to its owner once the patron is finished with it.

Figure 7 depicts the operation of the System level of the network. There are 18 Systems on this level of the Illinois network. Each System is responsible for a specified geographical area. With the exception of large academic libraries with collections in excess of 200,000 volumes and faculty requests, all individual libraries send their requests to the System level of the network.

The multiple output flows of the blocks in Figure 7 have probabilities associated with them. Thus, after in-processing and an initial search of the System's catalog, the librarian may either try to obtain the document from the System's shelves or, if the search was unsuccessful, try to verify the citation or forward the request. The sum of the probabilities of these three actions equals one.

In trying to obtain the document from the shelves, the librarian may find (perhaps with the circulation file) that the document is unavailable. In that case, the request would be forwarded. If the document is available, it would be outprocessed and delivered to the local library requesting it.

The System can forward the request to another local library in the System, another System (an informal procedure), or the Center level of the network. There are two ways in which a request can be forwarded to the Center level of the network. First, it can be sent to a Center with the specification that, if that Center cannot satisfy the request, the request should be sent back to the System. Alternatively, the request can be sent to a Center with the specification that, should the request not be satisfied, it should be forwarded to another Center. These two types of requests are called direct and referred requests, respectively.



SYSTEM LEVEL OF NETWORK

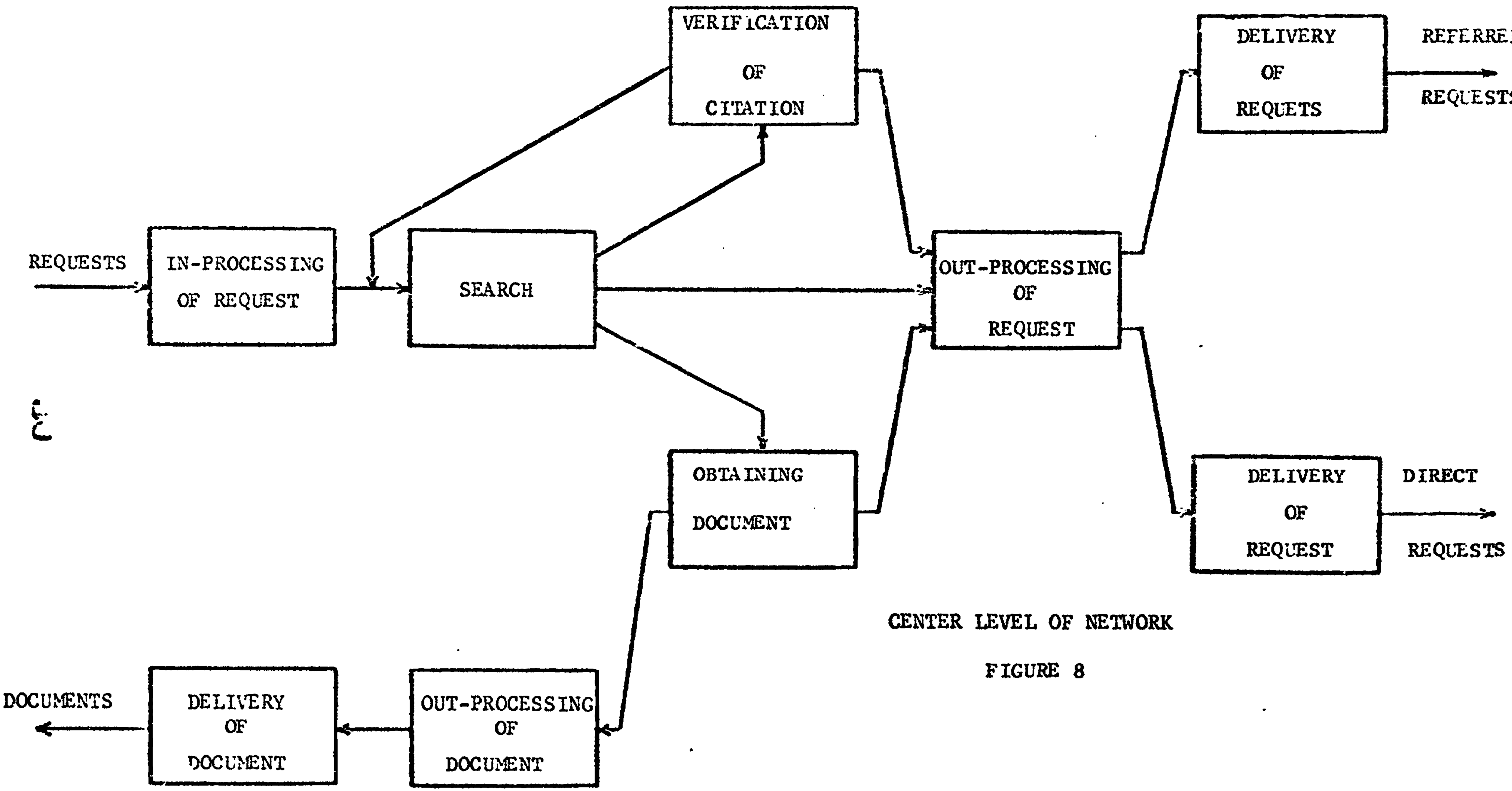
FIGURE 7

Regardless of where the request is forwarded, some time later the requested document or the unsatisfied request returns and three things can then happen. For a satisfied request, the document is out-processed and delivered. For an unsatisfied request, the request is either forwarded to some other source or the requestor is notified that the request cannot be filled.

An important point to note here is that requests or documents often have to wait in a line (queue) when they reach a processing point. This may be due to the fact that other requests are being processed and thus utilizing the processing resources at that point. Or, the request or document may have to wait for the daily mail pickup or for the delivery truck to leave. This queueing behavior is an important ingredient in the mathematical model that will be discussed in the next section of this report.

Figure 8 illustrates the operation of the Center level of the network. There are four Centers on this level of the network: Illinois State Library, Chicago Public Library, University of Illinois at Urbana-Champaign, and Southern Illinois University. The fourth level of the network includes Special Resource of which, John Crerar Library in Chicago is an example.

The operations depicted in Figure 8 should be fairly obvious from our discussions of the other two levels of the network. However, document delivery should be noted since there are two alternatives. A Center can send the document to the local library initiating the request or to the System through which it was forwarded. At the moment, Illinois State Library utilizes both alternatives while the other three Centers and the Special Resource Libraries use the second alternative.



CENTER LEVEL OF NETWORK

FIGURE 8

IV. MATHEMATICAL MODELING OF INTERLIBRARY LOAN NETWORK

The functional block diagrams of the previous section are a concise representation of the way that interlibrary loan requests flow through the Illinois network. In this section, we will further idealize the operations of the network to the point that they can be represented by equations.

This section will proceed as follows. First, we will discuss the need to predict network performance and how mathematical models can serve this purpose. Then, we will consider the various approaches that might be applied to modeling an interlibrary loan network. Finally, we will concern ourselves with how a model can be incorporated into an interactive computer program for use in planning and evaluation.

A. Predicting Network Performance

Library networks should be carefully planned [44,53,54]. Planning can take many forms. A group of individuals can rationally discuss an issue and reach a consensus of what policy to adopt. However, in a complex situation, there is no assurance that the consensus of a group discussion will be the "best" policy. Library networks can be very complex systems and an analytical approach to planning is needed.

The first stage in developing an analytical methodology for planning and evaluating library networks is the definition of a measure of performance. This is necessary because a policy can only be "best" or optimal with respect to some criterion. In a public or quasi-public system such as a library network, the criterion or performance measure should be service. A policy is optimal if, for a given level of expenditures, service is maximized. Alternatively, we might fix the level of service and minimize cost. Either way, the optimal policy results in the least cost per unit of service.

A reasonable definition of service for interlibrary loan networks should include two variables; probability of a request being satisfied and time delay in receiving the requested information or document [17,40]. Thus, the objective of a library network might be stated as maximizing probability of success (fill rate), minimizing delay, and minimizing cost. Unfortunately, minimum cost is not consistent with minimum delay and maximum probability of success. Therefore, the classical tradeoff between cost and service develops.

The resolution of this tradeoff is amenable to analysis but beyond the scope of this report. Instead, we want to consider how we can predict the components of network performance; delay, fill rate, and cost. If we can develop an approach to predicting performance, then we can consider optimization and the resulting tradeoffs.

B. Alternate Approaches to Modeling.

There are two basic approaches to analyzing and predicting network performance; network flow theory and queueing networks. Network flow theory [32,35] considers the problem of allocating flows in the various branches of a network so as to maximize the total flow through the network. Alternatively, network flow theory can be used to find the shortest path through a network where the measure of length may be time as opposed to distance. This approach to modeling was originally developed for communications networks but has been applied to library networks where message transfer was the operation of interest [6,43,50]. However, network flow theory is difficult to apply to networks where the flows are probabilistic or stochastic in nature. In stochastic networks, queues can build up in various places in the network and thus, the time required for a request to flow through the network becomes the sum of the servicing times at each processing point in the network plus the time spent waiting in queues.

Classical queueing theory [32,74] has, in recent years, been extended to consider queueing networks [2,41]. As with network flow theory, initial applications were to communication systems [41]. However, recent emphasis has been on computer systems [1,2,10,47] and, more recently, on public systems [87].

While queueing networks can adequately represent the possible stochastic nature of interlibrary loan requests, there are significant difficulties in calculating the performance (delay and fill rate) of such models. This has led many researchers to the use of simulation and computer programs such as GERTS [69,70,71], extensions of GERTS [33], and GNS [85] which have been developed for the simulation of stochastic networks. In trying to obtain statistically significant results, simulation can be costly and many investigators have resorted to approximations that permit analytical calculations of network performance [2,10,41,42,49,87]. While such approximations usually require simulation for validation and sensitivity analysis, once this has been achieved, the analytical approximations can then be used in place of simulation.

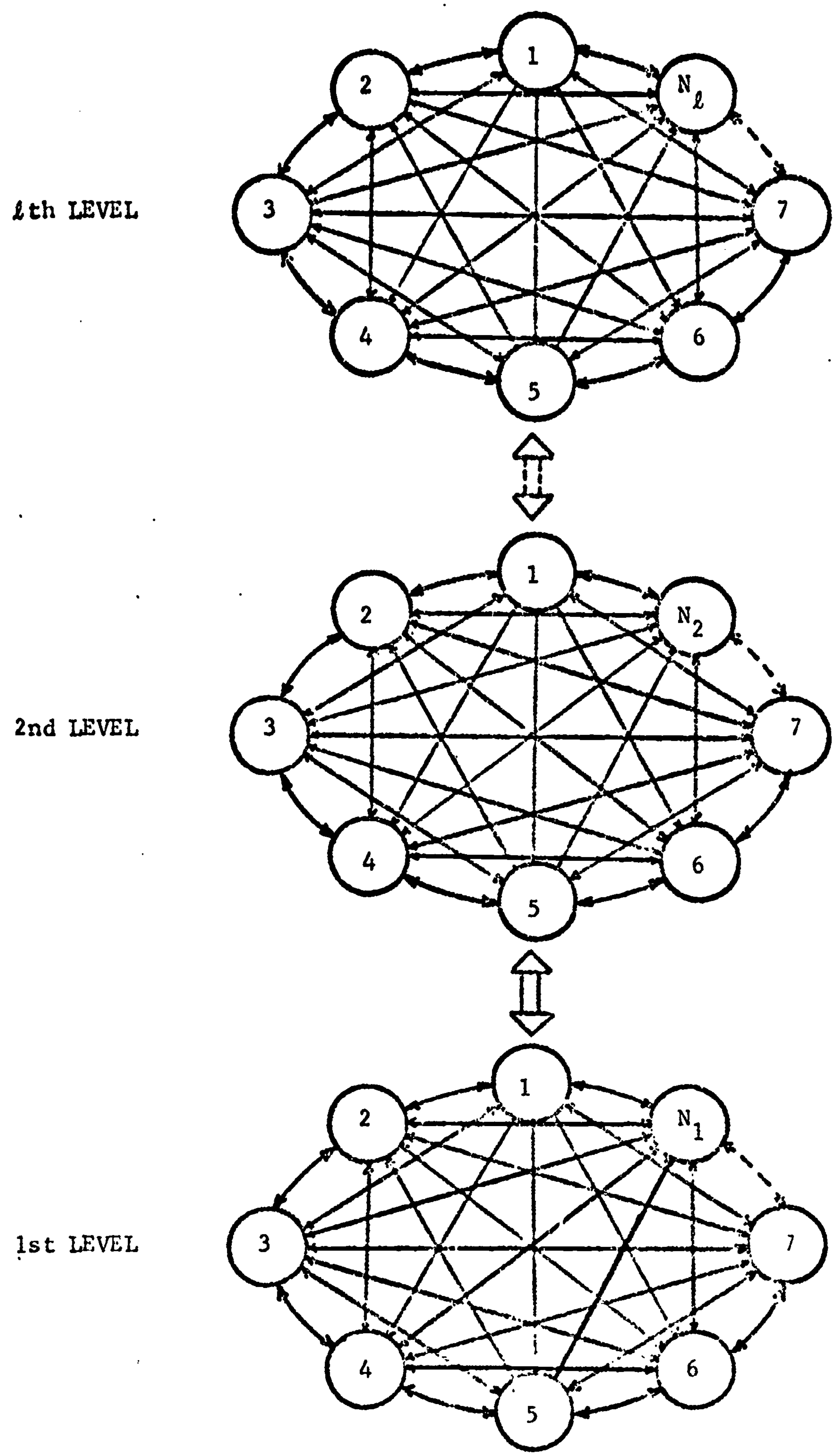
Another aspect of interlibrary loan networks that we wish to model is their hierarchical nature. The Illinois network displays this hierarchical property in that requests are first processed at the local level. Then, if not satisfied, they are processed on the System level and, if still not satisfied, processed on the Center level and possibly the Special Resource Library level. The hierarchical nature of library networks has been considered for several operations other than interlibrary loan networking [6,8,89]. However, hierarchical queueing networks have only recently received much attention [87].

C. Proposed Approach.

The approach adopted has been to model interlibrary loan networks in general as a hierarchy of distributed or completely connected networks. A distributed network is one in which every member has the possibility of dealing directly with every other member. While members of a network may choose not to exercise all of these options and thus some links may effectively not exist, such a situation can be modeled by assuming that the link does exist but that the probability of its use is zero.

This hierarchy of distributed queueing networks is illustrated in Figure 9. Within each of the ℓ levels, each member may deal directly with every other member. Between levels, a more restricted protocol is often used. However, if we assume that any member of the total network can deal directly with any other member of the total network, the hierarchical queueing network can be modeled as a single level network. Even if this assumption is employed, it is more conceptually satisfying to discuss a hierarchical network in the context of Figure 9.

To predict the probability of filling a request and delay in filling a request in such a hierarchical queueing network, analytical approximations are in the process of being developed. There are several crucial assumptions that should be discussed. The first assumption concerns the probability distribution of time between arrivals at processing points (Centers, Systems, etc.) in the network. It is necessary to assume that the form of this probability distribution of interarrival times is identical for all processing points in the network. However, the parameters of this distribution (i.e., the mean) may vary among processing points. While it was once thought that only very special types of networks fulfilled this condition [74], recent results have shown that this assumption is valid for many different types of networks [42,49].



HIERARCHY OF DISTRIBUTED QUEUEING NETWORKS

FIGURE 9

The next assumption concerns the effects of batching of requests. Batching need not be a conscious policy. At a highly decentralized processing point, batching may be a natural and desirable policy if the cost per request is to be minimized. There are approaches to analyzing batches processes [5]. However, if batch size were constant, then conventional, less elaborate queueing methods would apply. Unfortunately, batch size is not constant. Instead, it will be assumed that all of the effects of batching can be incorporated in the probability distribution for service time of a single request. This assumption certainly simplifies analysis and will be investigated through simulation.

The third assumption is that the next processing point that a request goes to depends only on the processing point that it is currently at. This certainly seems unrealistic. However, it has been suggested [2] that this difficulty can be avoided by creating classes of requests where the class to which a request is assigned depends on the number of processing points that the request has visited. This approach may also be of value for characterizing what appears to be a decrease in fill rate at each successive processing point in a given requests referral route.

The last assumption concerns the fact that the probability of a request being satisfied at a given processing point depends on the number of requests seeking the resources at that point. The number of requests seeking satisfaction at that point will depend on the probability of being satisfied at all the other processing points in the network. And, the demand and thus the probability of satisfaction at all the other processing points depends, in part, on the probability of satisfaction at the point in question. Thus, a cyclical character emerges where probability of satisfaction depends on demand which depends on probability of satisfaction etc. This relationship becomes fairly complex for networks with many processing points. Thus, we would like to assume that the relationship is very weak and can be ignored. The fact that the interlibrary loan demand on many network members is small compared to the demand from their local patrons would seem to make this assumption reasonable. Yet many networks may have some processing points almost exclusively devoted to interlibrary loans and this assumption will be further investigated for points such as these.

The analytical approximations under development can be used to predict the following measures of network performance.

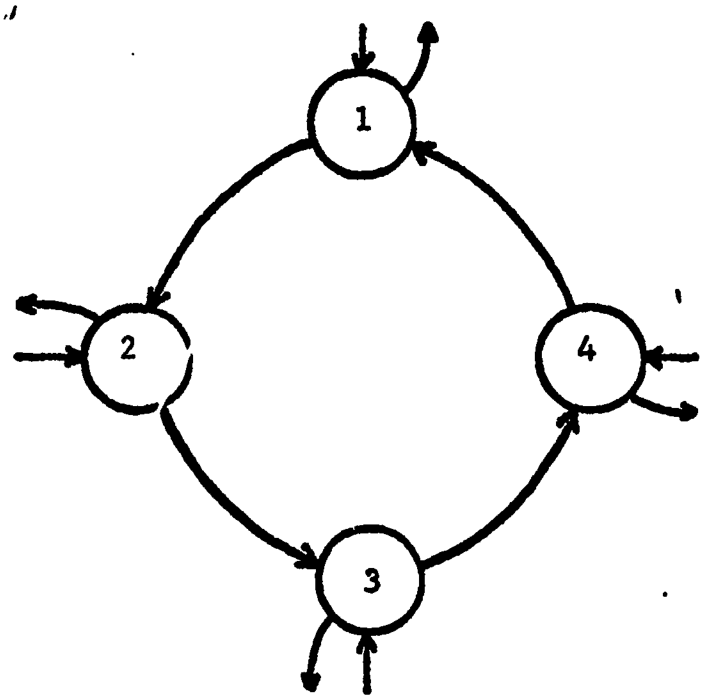
1. Average delay in filling a request,
2. Probability of filling a request,
3. Demand on each processing point,
4. Participation ratios [20],
5. Total and unit costs.

These predictions could be broken down into several categories including type of request (information, journal, monograph, etc.), subject area, type of requestor, etc.

This model will have several applications. It could be used to develop request routing procedures that minimize delay to the requestor. As will later be discussed, the model could be used to assess the effects of various applications of computer technology within a network. The effects of allocating staff and collection resources at various points in a network could be considered. For networks still in the planning stages, the model could be used with various location modeling procedures [26,72] to decide upon regions, location of centers, etc.

D. An Initial Model

An overall goal of this project is to produce an interactive computer package for the design and evaluation of library networks. In an effort to get an initial version of such a package on-line, the model illustrated in Figure 9 has been simplified to that of a simple ring network as shown in Figure 10.



SIMPLE RING NETWORK

FIGURE 10

The protocol assumed is as follows. A request received at Center i in subject area j is filled with probability p_{ij}. It is assumed that p_{ij} is constant and independent of demand on Center i and independent of the other Centers. If Center i cannot fill the request, it is referred to Center i + 1 unless Center i + 1 has previously seen the request. A request is deemed unfillable only after it has been to every Center without being filled.

Since Illinois does not use such a fixed ordering, this ring model is a rather poor and inaccurate representation of the Illinois network. The actual operation of the Illinois network is not as simplistic as the ring in Figure 10. However, this hypothetical structure has allowed us to define the necessary input data and develop an initial computer package. The input data required include:

1. Average processing time for filled and unfilled requests at each processing point in the network.
2. Average document delivery times between any two processing points.
3. Fill rates (p_{ij}) in each subject area at each processing point.
4. Probability of an item not being owned and probability of an item not being available for each subject area at each processing point.
5. Average demand (requests/year) in each subject area generated at the lowest level of processing points (e.g., local libraries).
6. Average demand currently allocated to each processing point.
7. Reimbursement schedule for all processing points.

Combining this data with the functional block diagrams in Figures 6 through 8 and the network structure in Figure 9 or 10, allows prediction of the network performance measures noted in the previous section (IV-C).

The interactive computer package that has been designed is called ILLINET which stands for Illinois Library and Information Network Model. It is a FORTRAN package designed to run on a time-shared computer with disk file storage. It could certainly be run in a batch mode with card or tape input but the versatility of the package would be greatly reduced.

To exercise ILLINET, the above data was necessary but not all available. From available data [15,27,62], gross estimates were obtained. At this point it should be emphasized that the very approximate nature of this initial model combined with out-of-date and inadequate data has caused the results discussed below to only be representative of the type of outputs produced by ILLINET and to have no meaning in an absolute sense.

We will not at this time discuss the detailed usage of ILLINET as that will be the subject of a later report. Basically, the user can formulate various network operating policies and see their effect on the measures of network performance. The user selects the measures that he wishes to see and they are displayed. The user can also select to have various tabulations printed on the line printer.

Tables 1 through 8 summarize the information available with ILLINET at the time of writing this report. However, as ILLINET is being modified and expanded almost daily, new options and tabulations will be available by the time this report is disseminated and read.

Table 1 reflects a policy of allocating an equal number of System requests per year, in each subject area, to each of the four Centers. Table 2 summarizes these System requests plus the referred requests by each Center. Note that in this example policy, referred requests account for more demand than System (or external) requests. Thus, demand generated by referrals can result in a significant load on the network.

Table 3 summarizes the satisfied requests while Table 4 summarizes the unsatisfied requests. Table 5 shows that 84% of the external requests are satisfied. It should be emphasized that all of the unsatisfied requests noted in Table 4 are due to the same request being unsatisfied at all Centers.

Table 6 summarizes the average time from the request entering the network to its receipt by the requestor. Table 7 summarizes the total and unit costs of the policy. Table 8 is a summary of the bottom rows of Tables 1 through 7.

TABLE - 1 ALLOCATION OF SYSTEM REQUESTS

SUBJECT	CENTER 1	2	3	4	TOTAL
PHIL	3845	3845	3845	3845	15380
SSCI	7926	7926	7926	7926	31703
LANG	731	731	731	731	2925
SCI	3633	3633	3633	3633	14531
TECH	5567	5567	5567	5567	22268
ARTS	4128	4128	4128	4128	16512
LIT	2335	2335	2335	2335	9341
HIST	3373	3373	3373	3373	13493
FICT	4741	4741	4741	4741	18965
BIOG	1793	1793	1793	1793	7171
OTHER	5543	5543	5543	5543	22174
TOTAL	43616	43616	43616	43616	174463

TABLE 2 - SUM OF SYSTEM AND REFERRED REQUESTS

SUBJECT	CENTER 1	2	3	4	TOTAL
PHIL	9202	7124	9549	8126	34000
SSCI	19597	17228	19888	18781	75494
LANG	1560	1082	1773	1241	5657
SCI	8004	7985	9110	7658	326[illegible]6
TECH	16174	12300	14914	13908	57296
ARTS	9883	7178	9434	9941	36435
LIT	5678	2779	4574	4737	17768
HIST	7451	6187	6831	7087	27556
FICT	16378	8296	10594	13302	48569
BIOG	5456	3562	4284	4519	17821
OTHER	13993	10265	13533	13485	51296
TOTAL	113375	83925	104485	102784	404569

TABLE 3 - SATISFIED REQUESTS

SUBJECT	CENTER 1	2	3	4	TOTAL
PHIL	5429	926	4774	2275	13405
SSCI	8619	3790	7558	5634	25801
LANG	1170	0	1224	372	2766
SCI	3201	1897	4555	2757	12410
TECH	8087	1599	5220	1947	16853
ARTS	6325	1364	3113	3678	14480
LIT	5167	472	2104	1326	9070
HIST	4322	2413	2801	2693	12228
FICT	11956	1576	1165	798	15495
BIOG	3328	712	1200	497	5737
OTHER	8396	1440	4737	4180	18752
TOTAL	66200	16190	38450	26159	146999

TABLE 4 - UNSATISFIED REQUESTS

	CENTER				
SUBJECT	1	2	3	4	TOTAL
PHIL	3773	6198	4774	5850	20595
SSCI	10778	13438	12331	13147	49694
LANG	390	1082	550	869	2890
SCI	4802	6008	4555	4901	20266
TECH	8087	10701	9694	11961	40443
ARTS	3558	5814	6321	6263	21955
LIT	511	2306	2470	3411	8698
HIST	3150	3774	4030	4394	15328
FICT	4422	6720	9428	12504	33074
BIOG	2128	2850	3085	4022	12084
OTHER	5597	8845	8797	9305	32544
TOTAL	47175	67735	66035	76625	257570

TABLE 5 - FILL RATES

	CENTER				
SUBJECT	1	2	3	4	TOTAL
PHIL	0.590	0.130	0.500	0.280	0.872
SSCI	0.450	0.220	0.380	0.300	0.814
LANG	0.750	0.000	0.690	0.300	0.946
SCI	0.400	0.240	0.500	0.560	0.854
TECH	0.500	0.130	0.350	0.140	0.757
ARTS	0.640	0.190	0.350	0.570	0.877
LIT	0.910	0.170	0.460	0.200	0.971
HIST	0.580	0.390	0.410	0.580	0.906
FICT	0.730	0.190	0.110	0.060	0.817
BIOG	0.610	0.200	0.280	0.110	0.800
OTHER	0.600	0.140	0.350	0.510	0.646
TOTAL	0.584	0.193	0.368	0.255	0.843

TABLE 6 - AVERAGE PROCESSING AND DELIVERY TIME IN DAYS

	CENTER				
SUBJECT	1	2	3	4	TOTAL
PHIL	5.72	9.37	8.38	5.86	7.33
SSCI	6.25	8.72	8.27	6.00	7.31
LANG	5.11	10.32	8.67	5.53	7.41
SCI	6.59	8.89	8.51	6.27	7.64
TECH	5.75	9.10	8.22	6.22	7.32
ARTS	5.12	6.72	7.93	5.18	6.73
LIT	3.82	9.06	8.09	4.69	6.42
HIST	5.43	8.09	8.23	5.43	6.80
FICT	3.90	8.27	7.49	4.94	6.16
BIOG	4.87	6.61	8.02	5.62	6.78
OTHER	5.35	8.50	8.01	5.43	6.94
AVERAGE	5.44	8.82	8.13	5.62	7.00

TABLE 7 - COSTS

STATUS	CENTER 1	2	3	4	TOTAL
FILLED	198599	48570	124963	78477	450608
UNFILLED	47175	67735	82543	76625	274079
TOTAL	245774	116305	207506	155102	724687
COST/FILL	3.71	7.18	5.40	5.93	4.93

TABLE 8 - SUMMARY

	CENTER 1	2	3	4	TOTAL
EXTERNAL	43616	43616	43616	43616	174463
TOTAL	113375	83925	104485	102784	404569
SATISFIED	66200	16190	38450	26159	146999
UNSATISFIED	47175	67735	66035	76625	257570
FILL RATES	0.584	0.193	0.368	0.255	0.843
DELAYS	5.44	8.82	8.13	5.62	7.00
TOTAL COSTS	245774	116305	207506	155102	724687
UNIT COSTS	3.71	7.18	5.40	5.93	4.93

E. Extensions in Progress

Current efforts are directed at four areas. The first is the use of a distributed model instead of a ring model. Also, processing time at each point will be made a function of the demand on that point. Third, the option of direct requests will be included. Lastly, the next lower level of the hierarchy (the System level in Illinois) will be added.

V. ALTERNATIVE COMPUTER AND COMMUNICATION TECHNOLOGIES

In this section the impact of computer and communication technology is discussed for six possible hardware applications. The six are not mutually exclusive and represent possible development directions rather than recommended systems. The impact of the most promising of the systems will be evaluated using the ILLINET model. Such evaluation will be the subject of a later report.

A. Inward WATS at Each System

Many of the member libraries are so small that it would be unrealistic to place computer terminals of any type on the premises. The only type of "communications technology" that can benefit these member libraries directly is the ordinary telephone which can serve as a very low cost "computer terminal." (The Ohio State Univesity LCS system in effect makes the entire 3,000,000 volume collection searchable from any telephone [62]).

If a System had inward WATS service and negotiated most inter-library loan requests via telephone there would be several advantages. Obviously, placing requests by telephone would eliminate the delay in-curred in sending the request to the System by mail or courier. In fact, local libraries do often telephone requests, but they must bear the telephone costs themselves which probably limits widespread use of the telephone.

Equally, important, the request form could be filled out at the System by an interlibrary loan clerk who would check the request for completeness and plausibility. Written requests can be sufficiently ambigious to make success in filling uncertain and it would seem that dialogue between requester and clerk would remove many of these ambiguities.

There are two costs associated with this service, the cost of the WATS service and the cost of the additional clerical support. Any reasonable request level would require unlimited WATS service at $650 per month. The extra clerical time obviously would depend on the average time to negotiate a request.

B. A Minicomputer for Circulation at the Systems and/or Centers

At the present time, at least one System and two Centers have created book-form or filmed catalogs of their holdings or a significant portion of their holdings. Such catalogs can serve as the basis for an automated system allowing remote access to their collections. In this section, the application of this idea on the System level will be emphasized.

If a System had a catalog of its holdings that included accession number as well as the usual bibliographic information and the System had a computer for on-line circulation control with inquiry by accession number as a feature, then it would be a straightforward extension of the circulation control system to permit direct inquiry and charging of materials by telephone.

The librarian at a member library desiring an item from the book catalog would telephone the computer and key in the accession number using the touch tone buttons. The computer response would be coded tones to indicate (a) available or (b) not available. If the item were available it could then be requested by keying in a number indicating the requesting library. The item would be charged to the requesting library at that instant (to prevent contention problems) and subsequently a printed message would direct a clerk to pull and ship the designated item.

Naturally, the installation of several compatible telephone inquiry systems would open the possibility of member libraries inquiring at at Systems other than their own.

Direct telephone inquiry and charging has many attractive features but is likely to be so expensive in development that it could be considered only if development costs were shared by several Systems. This sharing might be limited to design and programming costs on it might also include the sharing of computer hardware. In the latter case, one computer at a System or Center would serve several different Systems. The optimum number and placement of circulation computers to serve this function is related to hardware and communications costs.

C. A Central Switching Computer

With a central switching computer (CSC) all Teletype requests from the Systems level would be directed to a centrally located computer. Request messages would include a code for the subject area, location of the item if known and the usual bibliographic information. To promote acceptance of the system it might be necessary to permit the requesting System to specify routing to the Centers although, of course, Systems would be encouraged to let the computer determine routing. Format of the requests would be very similar to the present standard but some retraining of TWX operators would be needed because computer processing would require a more rigid format.

After each request message the CSC would respond with a diagnostic message (if the request were incomplete or unclear) or a computer-assigned message number to acknowledge an accepted request. The CSC would then route the request to one of the Centers on the basis of geography, subject area, processing load at the Centers and other factors.

After searching for the requested item the Center would TWX a "search result message" to the CSC consisting of the message number and a code to indicate success, in use, not owned, non-circulating, etc. The compactness of the Cen search result message would save keyboarding and transmission time at the Center but introduce the hazard that a single erroneous digit would completely chan the meaning of the message. To guard against this type of error the CSC would return a few characters of author and title as a type of "echo check."

There are numerous advantages to the use of such a "store-and-forward" message routing system. As previously mentioned, the use of a message number permits the search result message to be trimmed to the essentials with a consequent saving of Center staff effort. Additionally, the message number could be used by Systems to inquire into the current status of their requests. (Until recently, Systems submitting requests lost sight of the request until the item arrived or until all search possibilities had been exhausted. They now receive a separate status report for each item referred from one Center to another. There would appear to be advantages in a more selective inquiry system.)

In the existing network, each Center invests substantial effort in record-keeping activities such as logging requests, counting the number filled and unfilled, etc. These functions would be taken over by the CSC since it is obviously a simple extension of the message routing function. For the purpose of comparing Centers, data gathered this way would, of course, be more consistent than data gathered separately by the four Centers.

In addition to the record keeping required for budget and accounting purposes, the CSC would permit a wealth of data to be gathered on many other aspects of interlibrary loan service. These would include such things as the form of materials requested, statistics on service delay, success rates for classes of material, (e.g., Dewey classes) analysis of type of borrower, time variations in the processing load, etc. Initially, this data could be used to manually adjust the parameters of the routing algorithm for optimum service. Later, when the system was better understood, an adaptive routing algorithm could be implemented to dynamically adjust system parameters.

Computer based message switching systems (store and forward systems) are in fairly common use, a good example being the ARPA network. In terms of their use for interlibrary loan, message switching systems have been discussed in print [4] but no operating systems of the type discussed in this report are known to exist. Nelson Associates, for example, in their Report on the New York State ILL system [56] recommend the CSC concept ("...a necessary condition for improvement of NYSILL operation...") and appear to be heading in that direction [60]. They do quite properly point out that the design of such a system is likely to be a major undertaking. Because of the scope of the project, its innovative nature and its potential for application to libraries generally, the design of such a CSC might be supported by a research grant.

D. OCLC Terminals at Systems

Within the past four years the computer based cataloging network has gone from being an ambitious experiment to being the single computer application having the greatest impact on the entire library scene [34]. The success of OCLC has resulted in its rapid expansion plus the creating of similar networks in other parts of the country. In Illinois the four Centers joined OCLC in late 1974. It is generally assumed that OCLC membership will be extended to other libraries in the state within a few years.

The significance of OCLC and similar networks in terms of interlibrary loan is that the title file is essentially a union list of member holdings. Some member libraries have entered their entire holdings but most libraries enter only those items acquired after joining the network. Thus, the file must be regarded as an incomplete union list yet, one which improves with time.

OCLC terminals at the Systems level would obviously facilitate searching although the extent of this help is not certain. It would seem that most interlibrary loan requests are for "recent" materials but more complete data is needed.

At present, OCLC charges for cataloging use of the file (i.e., use for card production) and makes no charge for any other use of the file. This policy is likely to change, especially if terminals are used in a "search-mostly" mode as would be true for System use.

The OCLC network is not regarded by its developers as a shared cataloging network. They consider it a bibliographic network with cataloging as the first service offered. Other services such as serials control, circulation and acquisitions are in development It is entirely possible that they will offer an interlibrary loan service sometime in the future.

E. Commercial Time Sharing

Hayes [30] has written a report generally favorable to the use of commercial time sharing services for accounting and message switching. Such commercial services would compete with OCLC's (possible) interlibrary loan service in somewhat the same way that Bibnet [80] (a commercial cataloging network) competes with the OCLC cataloging service.

F. Facsimile Terminals at Systems

The prospect of moving a document from one location to another electronically is one that many librarians find fascinating. Several pilot projects have been described [9, 24, 56] but unfortunately the general conclusion in that the problems greatly outweigh the advantages. Problems include cost, quality of reproduction, inability to work with bound material, copyright and many other factors. Facsimile transmission of bound volumes can be dismissed from consideration for the near future. Facsimile transmission of journal articles is presently so expensive as to rule out its use except in special situations. Facsimile transmission of requests is technically feasible but more expensive than transmission by mail or TWX. Objections to facsimile based on cost might be reexamined if the widespread use of two-way table TV substantially lowers transmission costs.

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